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**Research Article / Araştırma Makalesi**

# The effects of whole-body vibration with plyometric training on physical performance in basketball players

# *Basketbol oyuncularında tüm vücut vibrasyonu eşliğindeki pliometrik eğitimin fiziksel performans üzerine etkisi*

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**ABSTRACT**

**Objective:** The aim of this study is to determine the effects of whole-body vibration (WBV) with plyometric training on physical performance parameters and balance in basketball players.

**Materials and Methods:** Professional basketball players (n=24, age 23.2±6.1 years) were randomly allocated to plyometric training (PT) and plyometric training with WBV (PT+WBV) groups (n=12 each). PT and PT+WBV groups received the same plyometric training program on a whole-body vibration platform for six weeks (two days a week) with routine basketball training. WBV was turned off for the PT group. Jumping performance, strength, speed, agility, flexibility and balance were assessed for all participants. We measured jumping performance using the vertical jump height, strength using the one-repetition maximum (1-RM) half-squat strength test, speed using the 20-meter speed test, agility using the T agility test, flexibility using the sit and reach test, balance using star excursion balance test (SEBT) before and after six weeks of plyometric training in both groups.

**Results:** At the end of six weeks of plyometric training, both groups revealed a significant increase in performance parameters and balance ($p<0.05$) comparing with pre-training. However, improvements in jumping performance, strength, speed and agility parameters, and balance were statistically greater in the group receiving whole body vibration compared with the plyometric training group ($p<0.05$).

**Conclusion:** Adding whole body vibration to plyometric training especially in professional athlete's workout programs can result in improvement in physical performance parameters including jumping performance, strength, speed, agility, flexibility, and balance.

**Keywords:** *Plyometric exercise, physical fitness, whole-body vibration*

**ÖZ**

**Amaç:** Çalışmanın amacı basketbol oyuncularında tüm vücut vibrasyonu eşliğinde yapılan pliometrik eğitimin, fiziksel performans parametreleri ve denge üzerine etkilerini incelemektir.

**Gereç ve Yöntemler:** Profesyonel basketbol oyuncuları basit rastgele yöntem ile (n=24, yaş ortalaması 23.2±6.1 yıl) pliometrik eğitim (PT) ve tüm vücut vibrasyon eşliğinde pliometrik eğitim (PT+WBV) grupları olarak iki gruba ayrıldı. PT ve PT+WBV grupları altı hafta (haftada iki gün) tüm vücut vibrasyon cihazı üzerinde aynı pliometrik eğitimle birlikte rutin antrenman programlarını devam ettirdi. PT grubunda tüm vücut vibrasyon cihazı kapalıyken eğitim verildi. Sıçrama performansı, kuvvet, hız, çeviklik, esneklik ve denge tüm sporcularda değerlendirildi. Her iki grupta da altı haftalık eğitim öncesi ve sonrasında sıçrama performansı dikey sıçrama yüksekliği, kuvvet 1 maksimum tekrar (1-RM) yarım skuat testi, hız 20 metre hız testi, çeviklik T çeviklik testi, esneklik otur-uzan testi, denge yıldız denge testi ile değerlendirildi.

**Bulgular:** Altı haftalık pliometrik eğitim sonunda her iki grupta performans ve denge parametrelerinde artış gözlendi ($p<0.05$). Tüm vücut vibrasyon eğitimi alan grupta sıçrama performansı, kuvvet, hız, çeviklik ve denge parametrelerinde pliometrik eğitim grubuna göre daha fazla artış gözlemlendi ($p<0.05$).

**Sonuçlar:** Profesyonel sporcuların antrenman programlarına dahil edilen vibrasyon eşliğinde pliometrik eğitimin sıçrama performansı, kuvvet, hız, çeviklik, denge gibi performans parametrelerinde artış sağlayacağını düşünüyoruz.

**Anahtar Sözcükler:** *Pliometrik egzersiz, fiziksel uygunluk, tüm vücut vibrasyon*

## INTRODUCTION

For many sports such as basketball that involve running, jumping, and throwing, the ability of the neuromuscular and musculoskeletal systems to create force at a certain velocity and in a specific direction appears to be essential. Sport-related demands that require vertically or horizontally oriented force application should be addressed thro–

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ugh training, according to the principles of training specificity (1). Factors including strength, speed and movement direction are viewed as significant variables in sports. Basketball players perform acceleration, deceleration and sudden changes in direction in the playing area (2,3). These changes are closely related to improvement in their strength, speed and agility (1). During dynamic movement, stretch and impact loads elicit eccentric muscle actions, with resulting elastic energy potentiating force production in subsequent concentric actions when coupling time is short. Effective use of the stretch-shortening cycle with quick movements is a significant aspect of athletic performance. This has been argued to have implications for planning performance-enhancing training in sports, and there is a wealth of literature supporting the principle of training specificity (3).

In light of aforementioned information, plyometric exercises can be used for augmentation of skeletal muscle's ability to exert maximal force in the shortest amount of time. Plyometric exercises consisting of bilateral jumps, hops, bounds, and running activities are based on the principle that rapid stretching of muscle leads to concentric contraction prior to eccentric contraction. Muscles undergo a shortening phase after the stretching phase. Plyometrics are designed to shorten the cycle between these two phases. Stretch-shortening cycle increases the ability of the muscle tendon unit to produce maximum power in the shortest period possible by bridging between power and speed in the muscle tendon unit (4,5).

Whole-body vibration (WBV) is a neuromuscular training, defined as the exposure of the entire body to mechanical vibration via an oscillating platform, and has been used as an alternative method to improve physical performance (6).Mechanisms of whole-body vibration for enhancing physical performance depend on neural factors like augmentation of motor unit synchronization, synergistic muscle activity, antagonist muscle inhibition, stretch reflex potentiality, and enhancement of muscle energy mechanism through vibration-generated contraction (7,8).

Some studies assessed the effects of WBV training protocols alone or in combination with conventional training in athletes, reporting inconclusive data on the effectiveness of WBV. Duc et al. investigated the effects of WBV on cycling sprint performance and found an increase only in power output with no changes in blood lactate level, heart rate and perceived exertion rate (9). In a study by Rasti et al., the effects of WBV on pain, vertical jump height, flexibility and agility were examined in young athletes with patellofemoral pain, and only improvement in flexibility was significant (10). The effects of WBV in taekwondo athletes revealed no improvement in jump height and maximal force with WBV (11). Four weeks of WBV with conventional training was effective in improving knee extensor isometric strength, squat jump height; however, speed and countermovement jump remained unchanged (12).

The present study aimed to determine the effects of 6-weeks of WBV combined with plyometric training on performance parameters such as jumping performance, strength, speed, agility and balance, compared with plyometric training alone in professional basketball players. We hypothesized that WBV with plyometric training can provide improvement in performance parameters and balance.

## MATERIALS AND METHODS

### Participants

Twenty-four male professional athletes were allocated to PT (n=12) and PT+WBV (n=12) groups using the simple random sampling method. Six members from each team were assigned to groups using the Research Randomizer version 4.0 (Urbaniak, GC & Plous). Inclusion criteria were age between 18-40 years, and no injury or surgery to lower extremities within the last three months. Athletes with a systemic, neurological condition or any other significant health problem within the past six months or during the study, and players leaving their teams during the study period were excluded from the study. One participant each from PT+WBV and PT groups were excluded from the study because of achilles tendinopathy and traumatic osteochondral lesion in the knee lateral condyle, respectively. Ultimately, the study was completed with 22 players.

Basketball training for both teams included technical and tactical drills 6-7 times a week, for approximately 90 minutes. The duration and frequencies of the training periods were similar in both teams. All participants trained and competed regularly in basketball competitions for at least seven years. The athletes participated in neither plyometric training nor WBV in the three months before the initiation of the study. This study received approval from the Ethics Committee of Hacettepe University (Approval no: 2015/17). Written informed consent was obtained from all study subjects.

### Experimental Approach

Plyometric exercise training was provided to both groups in addition to their basketball training twice per week for six weeks. Both groups were given plyometric training on the WBV platform, but the PT group received plyometric training when the platform was turned off. Subjects were asked to do their jumps with maximum effort avoiding a valgus knee position. Plyometric training sessions started with a 10 min warm-up workout, moved to a 35-40 min plyomet–

ric training program, and finished with cool down and stretching exercises for 5 min. Thirty second breaks between the sets and 2-min resting periods between the exercises were applied (Table 1). Athletes in the PT+WBV group performed the exercises on the WBV platform (Vibeplate, Nebraska, ABD) in the standing position. The WBV training protocol was adapted from previous studies (7,8). During the training, the amplitude of WBV was set to 2 mm; and the frequency was set to 25 Hz for the first two weeks, increased to 30 Hz in the second to fourth weeks, and to 35 Hz in the fourth to sixth weeks.

**Table 1.** Weekly plyometric training exercises

| Exercises | Weeks 1 and 2 | Weeks 3 and 4 | Weeks 5 and 6 |
|---|---|---|---|
| **Forward-backward jump** | Bilateral leg 3x12 | Single leg 3x10 | - |
| **Lateral jump** | Bilateral leg 3x12 | Single leg 3x10 | - |
| **Square jump** | Bilateral leg 3x12 | Single leg 3x10 | - |
| **Squat jump** | 3x12 | 4x12 | 4x15 |
| **Lunge jump** | 3x8 | 4x10 | Alternate leg 3x10 |
| **Single leg squat jump** | - | 3x8 | 3x10 |
| **Tuck jump** | - | 3x8 | 3x10 |
| **Power skipping** | - | 3x12 | 4x12 |
| **Bouncing jump** | - | - | 3x12 |
| **Multiple box jump** | - | - | 3x10 |

We assessed jumping performance, lower extremity strength, speed, agility and balance before and after six weeks of plyometric training (24 hours after the last training session). All assessments were conducted in two days with the following order: first day assessments included vertical jump, balance and horizontal jump tests. Second day assessments included speed test, agility test and strength test. For every measurement, three consecutive trials were performed with 2-min resting period between trails. Following each assessment, 15 min of resting periods were applied.

### *Jumping performance assessments*

The countermovement jump with arm swing (CMJas) test was used to assess jumping performance. CMJas was tested using a portable platform (Power Timer, Newtest, OY, Finland). The participants were told to start with their arms loose at the side of their bodies, and to jump as high as they could with arm swing. They were asked to do three maximum jumps for the test, and then the average of their jump heights in cm was recorded (13). The average value of three jumps was included in the analysis.

### *Muscle strength assessment*

Lower extremity muscle strength was measured using the one-repetition maximum (1-RM) half-squat test. In the 1-RM half squat test, the maximum weight that a person can lift once in a half squat position is determined (14).

### *Speed and agility assessment*

The 20-m speed test was conducted using a photocell timer to evaluate speed (Power Timer, New Test OY, Finland). To assess agility, the "Agility T-Test" was used. In both tests, timing of the participants was recorded in seconds (13).

### *Flexibility assessment*

The sit and reach test was used to assess flexibility on a sit-and-reach apparatus. For the test, the participant was asked to reach as far as possible, holding this position for 2 s, and the final position reached was considered. Two repetitions were recorded to the nearest cm, and separated by a rest period of 10 s (15).

### *Balance assessment*

The Star Excursion Balance Test (SEBT) was used to measure dynamic balance. To prevent the lower extremity length of the athlete from affecting the results, and to be able to record the score in percentages, adjustment was done by dividing the distance reached by each participant by his lower extremity length, and multiplying the quotient by 100 (13).

Before the assessments, all subjects were familiarized with testing protocols, and warmed up with sub-maximal jumping and jogging for five minutes. All assessments were conducted first before the training has started and then six weeks after the training.

### Statistical Analysis

SPSS 20.0 (SPSS Inc, Chicago, IL, USA) software was used for data analysis. The results were presented as mean ± standard deviation. All variables were tested for normal distribution using the Shapiro-Wilk test. The Wilcoxon test was used to compare differences between the groups before and after training. The Mann-Whitney U Test was used for comparison of pre-post differences between groups. For all tests, the significance level was set at 0.05.

## RESULTS

Baseline assessments are given in Table 2. Jumping performance was higher in the PT group at baseline assessments (p=0.039). No significant differences were found in anthropometric characteristics, strength, speed, agility, flexibility and balance at baseline assessments (p>0.05). The results for jumping performance, strength, speed, agility, flexibility and balance are demonstrated in Table 3 and Table 4. The PT+WBV group displayed significantly greater enhancement in flexibility, speed, agility, strength and jumping performance than the PT group (p<0.05, Table 3). For balance results after six weeks of training, both groups got augmentation in all directions (p<0.05, Table 4). The PT+WBV group had a higher increment in all other directions (p<0.05) comparing to the PT group, except for the posterior direction (p>0.05, Table 4).

**Table 2.** Baseline assessment of the athletes

| Parameters | PT+WBV (n=12) | PT (n=12) | Z | p |
|---|---|---|---|---|
| **Age** (yrs) | 22.5±5.0 | 24.0±7.0 | -0.138 | 0.890 |
| **Height** (m) | 1.95±0.1 | 1.94±0.1 | -0.230 | 0.818 |
| **Body weight** (kg) | 89.5±11.1 | 91.1±10.0 | -0.090 | 0.921 |
| **BMI** (kg/m²) | 23.2±1.8 | 23.9±1.1 | -0.699 | 0.485 |
| **CMJas** (cm) | 39.6±6.7 | 45.6±6.5 | -2.069 | **0.039***|
| **Max. strength** (kgf) | 123.6±26.8 | 126.4±30.3 | 0.230 | 0.818 |
| **Speed** (s) | 3.3±0.2 | 3.3±0.1 | -0.033 | 0.974 |
| **Flexibility** (cm) | 12.6±5.8 | 12.6±5.5 | -0.033 | 0.974 |
| **Agility** (s) | 9.9±0.3 | 9.8±0.5 | -0.427 | 0.669 |
| **SEBT Anterior** | 91.8±6.8 | 92.9±8.9 | 0.295 | 0.768 |
| **SEBT Anterolateral** | 83.3±6.2 | 81.3±6.8 | 0.952 | 0.341 |
| **SEBT Lateral** | 73.9±10.4 | 72.7±10.9 | 0.164 | 0.870 |
| **SEBT Posterolateral** | 84.9±10.6 | 89.6±9.2 | 0.657 | 0.511 |
| **SEBT Posterior** | 97.7±11.0 | 93.4±11.0 | 0.033 | 0.974 |
| **SEBT Posteromedial** | 99.8±6.9 | 100.9±7.5 | 0.361 | 0.718 |
| **SEBT Medial** | 95.3±8.2 | 94.4±7.9 | 0.361 | 0.718 |
| **SEBT Anteromedial** | 93.8±7.6 | 93.2±7.4 | 0.361 | 0.718 |

Figures as X±SD; *: p<0.05; PT+WBV: plyometric training with whole body vibration group; PT: plyometric training group; CMJas: countermovement jump with arm swing; SEBT: star excursion balance test, as cm.

**Table 3.** The effects of 6-week PT and PT+WBV training on performance

| Parameters | Groups | Pre-test | Post-test | Z | p |
|---|---|---|---|---|---|
| **CMJas** (cm) | PT+WBV | 39.6±6.7 | 44.5±6.3 α | -2.93 | 0.003* |
| | PT | 45.6±6.5 | 48.2±5.6 | -2.84 | 0.004* |
| **Muscle strength**(kgf) | PT+WBV | 123.6±26.8 | 134.1±27.2 ¥ | -2.96 | 0.003* |
| | PT | 126.4±30.3 | 131.4±30.3 | -2.81 | 0.005* |
| **Speed** (s) | PT+WBV | 3.3±0.2 | 3.1±0.1 Δ | 2.94 | 0.003* |
| | PT | 3.3±0.1 | 3.2±0.1 | 2.93 | 0.003* |
| **Agility** (s) | PT+WBV | 9.9±0.3 | 9.6±0.3 ß | 2.94 | 0.003* |
| | PT | 9.8±0.3 | 9.7±0.4 | 2.93 | 0.003* |
| **Flexibility**(cm) | PT+WBV | 12.7±5.8 | 15.5±5.8 ∂ | 2.94 | 0.003* |
| | PT | 12.6±5.5 | 14.5±5.6 | 2.94 | 0.003* |

*: p<0.05; PT+WBV: plyometric training with whole body vibration group; PT: plyometric training group; CMJas: countermovement jump with arm swing. Post testing differences between PT and PT+WBV, α and ß: p=0.001; ¥: p=0.005; Δ: p=0.015; ∂: p=0.006.

**Table 4.** The effects of 6-week PT and PT+WBV training on balance

| Position | Group | Pre-test | Post-test | Z | p |
|---|---|---|---|---|---|
| **Anterior** | PT+WBV | 91.8±6.8 | 96.3±6.4 α | -2.937 | 0.003* |
| | PT | 92.9±8.9 | 95.3±9.0 | -2.941 | 0.003* |
| **Anterolateral** | PT+WBV | 83.3±6.2 | 87.8±6.8 ß | -2.934 | 0.003* |
| | PT | 81.3±6.8 | 84.3±6.5 | -2.936 | 0.003* |
| **Lateral** | PT+WBV | 73.9±10.4 | 78.1±10.5 Ø | -2.937 | 0.003* |
| | PT | 72.7±10.9 | 75.0±1.0 | -2.805 | 0.005* |
| **Posterolateral** | PT+WBV | 84.9±14.6 | 88.5±14.4 ∂ | -2.937 | 0.003* |
| | PT | 89.6±9.2 | 91.9±8.7 | -2.940 | 0.003* |
| **Posterior** | PT+WBV | 97.7±11.0 | 100.9±10.4 | -2.847 | 0.004* |
| | PT | 97.4±11.0 | 99.9±10.3 | -2.714 | 0.007* |
| **Posteromedial** | PT+WBV | 99.8±6.9 | 103.3±6.0 § | -2.937 | 0.003* |
| | PT | 100.9±7.5 | 103.0±7.5 | -2.670 | 0.008* |
| **Medial** | PT+WBV | 95.3±8.2 | 99.1±7.3 ¥ | -2.936 | 0.003* |
| | PT | 94.4±7.9 | 96.7±7.6 | -2.758 | 0.006* |
| **Anteromedial** | PT+WBV | 93.8±7.6 | 97.1±7.9 Ω | -2.934 | 0.003* |
| | PT | 93.2±7.4 | 95.2±7.2 | -2.938 | 0.003* |

Figures as X±SD for SEBT in cm; PT+WBV: plyometric training with whole body vibration group; PT: plyometric training group; *: p<0.05 pre-test vs. post-test. Post testing differences between PT and PT+WBV, α: p<0.001; ß: p=0.014; Ø: p=0.005; ∂: p=0.018; §: p=0.016; ¥: p=0.03; Ω: p=0.006.

## DISCUSSION

The study aimed to investigate whether plyometric training combined with whole body vibration has a beneficial effect on jumping performance, muscle strength, speed, agility, flexibility and balance in basketball players. Six weeks of PT with WBV training improved performance parameters except for balance in posterior direction. Consequently, the study findings supported our hypothesis that plyometric training combined with WBV enhances physical performance parameters.

There are inconsistent data in literature regarding the effects of WBV on jumping performance and muscle strength. Some studies displayed positive effects of WBV training on these parameters, when added to exercise training. Mahieu et al. conducted a study in young skiers to investigate the effects of squat and jump exercises with WBV at increasing amplitude and frequency. After six weeks of training, 25% larger improvement was achieved in the explosive strength of ankle and knee muscles. comparing to equivalent resistance training (16). Despite the use of different training methods, explosive muscle strength was similarly increased in the current study.

WBV elicits reflexive muscle contraction by activating motor neurons extensively via sensory stimuli. In many studies, exposure to vibration has been reported to increase muscle activity in healthy people and athletes (6,17,18). In present study, providing more sensory input to extremities during plyometric exercises might have enhanced the muscular activation, neuromuscular coordination, and also increased maximal muscle strength.

Jumping performance is one the most important parameters that affects overall performance in basketball players. In a study by Ronnestad, squat exercises were applied to recreational young athletes on a vibration platform for five weeks, and after the training, an 8.7% increase was observed in vertical jump (18). Torvinen et al. examined the effects of vertical WBV in healthy individuals aged between 19 and 36 years, and found an increase in CMJ and vertical jump performances (19). In our study, after the plyometric training combined with WBV, the increase in CMJ performance was 12%, which is higher comparing to other studies. This finding may be explained by an additional contribution to vertical jump distance provided by plyometric training, resulting in augmented muscle strength and better performance. Colson et al. reported that after four weeks of WBV training, squat jump performance increased significantly but no differences were observed in CMJ and drop jump performances (12). We consider that variations in reported performance might be related to differences in the frequency and amplitude of WBV training, session time, and exercise protocols.

Basketball is regarded as an intermittent, high-intensity sport that involves explosive actions such as quick and repeated accelerations, decelerations, jumps and direction changes. For these types of explosive actions, athletes need to move as quickly as possible in a short time. The increase in speed was 6% in the group receiving plyometric training combined with WBV, whereas the PT group displayed a 4% increase in speed.

In one study, athletes displayed 2-3% increase in their sprint speed following WBV training three times a week for six weeks (20). Sprint performance of ice hockey players increased by 1-3% after WBV exercises combined with body-loaded half-squats (17). In contrast, no changes were detected in speed after six weeks of WBV training in basketball players aged 14-15 years (21). Gerakaki et al. reported noticeable changes in 60 m sprint times in well-trained track and field sprinters (22). Kavanough et al. and Roberts et al. used a single WBV bout of 30 and 60 seconds with vibration and found no significant differences in sprint performance between WBV and sham (23,24). These findings demonstrate that WBV training significantly contributes to high-speed movements by providing specific training for fast twitch muscle fibers. Also, augmentation of speed can be attributed to the beneficial effect of vibration training on muscle strength when added to plyometric training.

Agility is defined as the ability to move and change the direction and position of the body quickly while maintaining balance and speed. Agility and speed are thought to be significant physical attributes of good performance (3). In the current study, the agility test time decreased by 3.1% in the PT+WBV group, and the T-agility test was completed in a shorter time, compared with only a 1.4% reduction observed in the PT group, demonstrating a significant improvement in agility. Wallmann et al. examined the acute effects of static exercise training combined with WBV in healthy adults using an agility T-test, and reported that after only one session, agility increased (25). Following a 5-week training with increasing vibration frequency, improved agility was observed in healthy sedentary adults with both low-amplitude and high-amplitude WBV training (26). For agility, there needs to be an increase in performance parameters such as power and strength to enable sudden changes in speed and movement direction. At the same time, neural adaptation and increased motor unit recruitment are other factors that can cause improvement in agility test scores (5). This is why we think that increase in power and strength with WBV training has a positive effect on agility as well (27).

Flexibility has an important role in injury prevention and sports performance. In athletes, decreased hamstring flexibility was found to be associated with diminished jumping performance (10). In our study, flexibility increased by 22.9% in the PT+WBV group versus only 15.5% in the PT group receiving plyometric training alone. In a study in elite female field-hockey players, participants exercised on a WBV platform, and flexibility was measured with a sit-and-reach test. At the end of the study, an 8.2% increase was recorded in flexibility (15). In female athletes, 10-15 min of static exercise training on a WBV platform three-days-a-week for eight weeks produced 13% increase in flexibility performance as measured by the sit-and-reach test (28). A literature review concluded that combining WBV with routine exercise training resulted in significantly greater improvements in flexibility (29).

Increased blood flow in the muscles, which can raise the temperature of muscle fibers and lead to better muscle flexibility, can be explained by improved flexibility after WBV. Furthermore, WBV can cause an inhibitory effect in muscles by stimulating Golgi tendon organs, and affecting Ia inhibitory interneurons in antagonist muscles, releasing the muscle and improving its flexibility. In the current study, it was observed that different types of exercises combined with vibration elicited an increase in flexibility, and the choice of exercise may affect the level of flexibility improvement (28). Even though temperature and electromyographic measurements were not obtained in the present study, the possibility of a neural and mechanical adaptation mechanism underlying the flexibility gains cannot be excluded. Previous WBV studies, while lacking in direct measurements, have attributed improved flexibility to the aforementioned adaptation mechanisms.

In basketball, twisting movements during jump shots, rebounds, penetrations into the defensive perimeter, and dribbling actions with physical contact challenge athletes' balance. In practically every sport, good balance is required for success, and it also improves athletic performance (13). Dancers with unilateral functional ankle instability were assessed for balance and muscle function after performing dynamic exercises twice a week for six weeks on a WBV platform. SEBT results displayed 5-16% improvement in balance in various directions (30). However, no improvement in posterior direction was observed in the study. We believe the reason for this is that no exercises were carried out in the posterior direction.

In one study, male athletes with anterior cruciate ligament injury performed static and dynamic exercises in combination with WBV for three days a week over a month after 12 weeks of physiotherapy. A significant improvement within a range of 35-47% was observed in postural stability (31). Greater improvement in balance after dynamic exercises with vibration comparing with other treatments can be related to the somatosensory effect of vibration on postural control. Improved balance in the whole-body vibration group can be attributed to increased strength production capacity after training increases (32,33). This action occurs via stimulation of motor units and increased co-contraction of synergistic muscles (34).

In the present study using vibration together with plyometric exercises, enhanced balance was reinforced due to aforementioned mechanisms. Vibration stimulates proprioceptors in the foot sole. Furthermore, with stimulation of proprioceptors, the stretch reflex and cutaneous reflex are triggered, and an increase in muscular power is observed. Athletes establish better balance control strategies owing to the increase in muscular strength, motor unit firing synchronization, and the positive effects of co-contraction of synergistic muscles produced by whole body vibration training (8,35). With the repetition of these stimuli, postural control strategies are readjusted, resulting in improved postural stability (31,34).

## CONCLUSION

Professional sport activity requires a combination of physical fitness parameters including agility and muscular strength. Balance, speed, agility, and coordination are important components for precise, rapid movements, and all of these components have an impact on an athlete's sports performance. In the current study, plyometric training with whole body vibration produced greater improvement in lower extremity performance parameters compared with plyometric training alone in basketball players.

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